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External Auditory Exostosis in Prehistoric Chilean Populations: A Test of the Cold Water Hypothesis

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ABSTRACT Over one thousand prehistoric crania (n = 1,149) from northern Chile were analyzed to determine if the presence of external auditory exostosis (EAE) was a type of subsistence-induced pathology, a consequence of habitual fishing in the cold water of the Pacific Ocean, rather than genetically determined. To test this occupational hypothesis, the sample was divided according to chronology, type of economy, site elevation, and sex. The crania came from 43 sites, including the coast, lowland valleys (100–2,000 m), and highlands (2,000 to 4,000 m) with a time frame of 7,000 B.C. to the Inca era (1500 A.D.). There was a significant association between EAE, environment, and sex. The coastal inhabitants had the highest prevalence of EAE with 30.7% (103/336), followed by 2.3% (6/264) for the valley people and 0% (0/549) for highlanders. Coastal and valley men were significantly more affected than their female counterparts. Contrary to expectations, there was no significant association between EAE and economy and/or chronology. In the Arica area, the early Chinchorro fishers, without agriculture, had 27.7% (26/94) EAE, the subsequent agro-pastoralists, 42.7% (32/75), and the late Arican agro-pastoral fishers had 35.6% (36/101) EAE. Apparently, with the advent of agriculture, the coastal Arican populations increased their ocean harvests, rather than decreased them, to gain a surplus in order to trade with nonmaritime groups. Am J Phys Anthropol 103:119–129, 1997.

This paper explores the incidence of external auditory exostosis (EAE) in ancient Chilean populations during the last 9,000 years. The goal is to test whether EAE was the outcome of genetic or environmental forces, such as exposure to cold water. To achieve this goal, a wide range of archaeological populations with diverse modes of subsistence and economies were studied, from hunter-gatherers to agro-pastoral societies. Likewise, archaeological sites from different elevations and econiches were considered, ranging from sea level to highland (approximately 4,000 m).

EAE consists of an osseous proliferation that develops at the entrance of the auditory canal. Macroscopically they are spheroid or oval, looking like a pea or a small bean, and can grow to completely block the auditory canal (Adams, 1951; Filipo et al., 1982; Fowler and Osmun, 1942; Frayer, 1988; Graham, 1979; Gregg and Bass, 1970; Hrdlicka, 1934; Kennedy, 1986; Standen et al., 1985; Weiss, 1961, 1970). Two hypotheses have attempted to explain the origin of EAE. The first postulates that EAE is geneti-

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cally transmitted, and as such EAE has been used as one of many traits to measure genetic distances between ancient populations (Berry and Berry, 1967; Rotthammer et al., 1984). The second, is that EAE is an acquired condition, a consequence of the environment, specifically, the result of continuous exposure to cold water activities, such as diving, underwater pressure, ocean navigation, and aquatic sports. Plenty of clinical evidence exists supporting the latter hypothesis (Dibartolomeo, 1979; Filipo et al., 1982). Continuous exposure to cold water can trigger a local reaction of the ear's soft tissue, which leads to the stimulation of osteogenic cell activities and, finally, an exostosis. Only in a few cases does the trigger agent correspond to an infectious process and, in such cases, a generalized hyperostosis of the ear canal would be noted, rather than a unique growth with well-defined margins (Van Gilse, 1938, in Kennedy, 1986).

The etiology of EAE as a result of cold water exposure has been clinically demonstrated, but this association has rarely been applied to archaeological samples. An exception is Gail Kennedy (1986) who conducted a superb analysis of EAE in a worldwide survey, which correlated the relationship to latitude and water temperatures. She found that populations living between 30–45° of north and south latitudes had a greater incidence of EAE. Interestingly, in these latitudes the water temperatures are below 19°C. Thus, using Kennedy's finding and the clinical evidence, all prehistoric populations harvesting in low temperature waters should present significant evidence of EAE. In our area of study, Standen et al. (1985) found that EAE had a long history, and was already present in the hunter-gatherer-fishers of coastal northern Chile, starting 8,000 years ago. Bilateral and well-developed EAE were also present in the Acha man, the oldest human sample from Arica dated to 7020 B.C. (Arriaza et al., 1993). In nearby Andean areas, other researchers have also found this condition associated almost exclusively with populations that exploited coastal environments (Benfer, 1990; Bonavia, 1988; Frayer, 1988; Quilter, 1989, p. 21; Tattersall, 1985; Weiss, 1961).

Using the clinical evidence for EAE (the cold water and irritation correlation) and the prevalence of EAE noted in some ancient populations, we tested the hypothesis that the presence of EAE in Chilean archaeological samples was the consequence of subsistence activities or an activity-induced pathology. Harvesting from the ocean, or rivers, as in gathering shellfish, often requires water immersion for a sustained period. To assess this as a subsistence-induced pathology, various archaeological coastal, inner valley, and highland populations were studied (Tables 1–4). If the presence of EAE was indeed a subsistence-induced pathology, it should show an inverse correlation with altitude and geographic distance from the coast. As proposed by Standen et al. (1985), Chilean coastal populations should have the highest incidence compared to highlanders. If the subsistence hypothesis is correct, people living in the sierra and highlands should have no evidence of EAE. If on the contrary, EAE has a genetic base, then a random distribution of the trait would be expected, independent of geography, due to closer genetic affinities of Arica populations.

In general, food-related activities, gathering and/or processing, are based on gender. Thus, influenced by our previous studies (Standen et al., 1985), significant EAE differences should be noted between males and females, with a higher incidence present in males.

From a chronological perspective, the Archaic Arican populations (7000–2000 B.C.) had a greater maritime dependence than the people of the Formative Period (after 1500 B.C. to 500 A.D.) and, thus, the former should show a higher incidence of EAE. During the Formative Period the introduction of maize, beans, fruits, tubers, and camelids implied a shift in subsistence with less reliance on coastal products (Nuñez, 1989; Muñoz, 1989). Therefore, Formative populations should show a low incidence of EAE. Hypothetically, EAE should be even lower in late agro-pastoral populations (1000 to 1450 A.D.) due to the fuller development of agriculture and land-based subsistence.

Lastly, different authors have postulated a continuous interaction among the coast and inner valleys starting from the Archaic

TABLE 1. Incidence of EAE in sites of the fertile coast (river mouths)

	Individuals studied				Individuals with exostosis							
Sites	N	F	M	I	n	F	M	I	%	Economy	Dates	Source[1]
Acha 2	1	—	1	—	1	—	1	—	100.0	Fishing-gathering	7020 B.C.	(1–3)
Acha 3	2	—	2	—	1	—	1	—	50.0	Fishing-gathering	6170 B.C.	(4)
Camarones 14	12	5	6	1	2	—	1	1	16.6	Fishing-gathering	5050 B.C.	(5)
Camarones 17	1	1	—	—	0	—	—	—	00.0	Fishing-gathering	4905 B.C.	(1–3)
Maderas Enco	2	1	1	—	2	1	1	—	100	Fishing-gathering	2800 B.C.	(6)
Morro 1	52	23	28	1	15	3	11	1	28.8	Fishing-gathering	3210–1720 B.C.	(7–8)
Morro 1/6	15	6	7	2	1	—	1	—	6.7	Fishing-gathering	2360–1945 B.C.	(9)
Playa Miller 8	9	3	4	2	4	1	2	1	44.4	Fishing-gathering	2140 B.C.	(10–12)
Pta. Teatinos	66	30	36	—	9	1	8	—	13.6	Fishing-gathering	2050 B.C.	(13)
Quiani 7	4	2	2	—	2	1	1	—	50.0	Fishing-gathering	1650 B.C.	(14)
Camarones 15	5	1	4	—	3	—	3	—	50.0	Fishing-agriculture	1050 B.C.–450 A.D.	(15)
Playa Miller 7	59	29	30	—	24	12	12	—	42.4	Fishing-agriculture	560 B.C.	(16)
Garibaldi C1	1	1	—	—	1	1	—	—	100.0	Fishing-gathering	50 B.C.	(17)
Playa Miller 4	35	11	21	3	15	3	11	1	42.9	Fishing-agriculture	1150 A.D.	(18)
Camarones 8	8	6	2	—	0	0	0	—	00.0	Fishing-agriculture	1350 A.D.	(18)
Camarones 9	12	6	5	1	7	2	4	1	58.3	Fishing-agriculture	1410 A.D.	(18)
Total	284	125	150	9	87	25	58	5	30.6			

[1] (1) Muñoz et al., 1993; (2) Arriaza et al., 1993; (3) Aufderheide et al., 1993; (4) Standen and Santoro 1995; (5) Schiappaccase and Niemeyer, 1984; (6) Arriaza, 1994; (7) Allison et al., 1984; (8) Standen et al., 1984; (9) Focacci and Chacón, 1989; (10) Alvarez, 1969; (11) Rivera, 1984; (12) Soto, 1974; (13) Quevedo, 1975; (14) Dauelsberg, 1974; (15) Munñoz et al., 1991; (16) Focacci, 1974; (17) Standen and Santoro, 1995; (18) On file Lab. Antropología Física, Universidad de Tarapacá.

TABLE 2. Incidence of EAE in sites of the dry coast

	Individuals studied				Individuals with exostosis							
Sites	N	F	M	I	n	F	M	I	%	Economy	Dates	Source[1]
Cañamo 3	6	2	3	1	2	—	1	1	33.3	Fishing-gathering	365 B.C.	(1)
Auto Club	6	2	4	—	0	—	—	—	00.0	Fishing-gathering	ca. 750 A.D.	(2)
Los Verdes 1	18	—	—	18	2	—	—	2	11.0	Fishing-gathering	ca. 1350 A.D.	(3)
Pta. Blanca	22	—	—	22	12	—	—	12	54.5	Fishing-gathering	ca. 1450 A.D.	(2)
Total	52	4	7	41	16	—	1	15	30.8			

[1] (1) Munizaga, 1976 Ms in Núñez, 1983; (2) Costa and Sanhueza, 1976; (3) Sanhueza, 1978, 1985.

(Chinchorro) to the late Inca Period (Hidalgo and Focacci, 1986; Núñez, 1983; Santoro, 1980a,b; Schiappacasse and Niemeyer, 1984). Chronologically, the interaction became more evident during the Middle Period (500 to 1000 A.D.) when the lowland valleys were simultaneously occupied by various ethnic groups (Berenguer and Daueslberg, 1989; Focacci, 1985). They reported that various subsistence bases, restricted by elevation differences, were part of a complementary system where agricultural populations of the inner and upper valleys had access to coastal products through trade with the coastal fishermen, rather than by direct acquisition. As part of the hypothesis, minimal incidence of EAE in the inland valley people was predicted. If, on the other hand, inland populations had a high incidence of EAE it would point to a direct harvesting from the ocean.

MATERIALS AND METHODOLOGY

A total of 1,149 crania, excavated from 43 archaeological sites, were studied for evidence of EAE (Tables 1–4). All were located in northern Chile between the 17° 30′ to 26° 30′ latitude south, except Punta Teatinos, which is located further south. The cemetery sites represent coastal, valley, and highland locations (Fig. 1). Most of the crania studied were housed at the Museo Arqueológico San Miguel de Azapa of the University of Tarapacá. With exception of two Colonial sites, the cemeteries were prehispanic covering a chronological range of 7000 B.C. to 1450 A.D. All of the cemeteries have been extensively studied from a bioarchaeological perspective and many have radiocarbon dates for selected samples (Allison, 1980; Allison et al., 1981, 1982; Arriaza, 1994, 1995; Aufder-

TABLE 3. Incidence of EAE in the valley sites (10–100 km from the coast)

	Individuals studied				Individuals with exostosis							
Sites	N	F	M	I	n	F	M	I	%	Economy	Dates	Source[1]
Tiliviche 2	12	6	6	—	0	0	0	—	00.0	Hunting-gathering	1830 B.C.	(1)
Tarapaca 40	5	4	1	—	0	0	0	—	00.0	Gathering-agricul.	360 B.C.	(2)
Azapa 70	14	8	6	—	3	1	2	—	21.4	Agriculture	490 B.C.	(3–4)
Azapa 14	10	5	5	—	2	2	—	—	20.0	Agriculture	400 B.C.	(5)
Azapa 115	9	6	3	—	0	0	0	—	00.0	Agriculture	ca. 550 B.C.	(6)
Azapa 140	59	38	21	—	0	0	0	—	00.0	Agriculture	ca. 750–950 A.D.	(7)
Azapa 71	53	38	15	—	0	0	0	—	00.0	Agriculture	ca. 650–950 A.D.	(8)
Azapa 8	22	16	6	—	0	0	0	—	00.0	Agriculture	ca. 650–950 A.D.	(9)
Azapa 75	15	7	8	—	0	0	0	—	00.0	Agriculture	ca. 560 A.D.	(7)
Azapa 141	7	2	5	—	0	0	0	—	00.0	Agriculture	ca. 700 A.D.	(7)
Azapa 11	5	4	1	—	0	0	0	—	00.0	Agriculture	860 A.D.	(9)
Azapa 6	32	12	20	—	1	0	1	—	3.2	Agriculture	400–1150 A.D.	(9)
Molle Pampa	5	3	2	—	0	0	0	—	00.0	Agriculture	ca. 1350 A.D.	(7)
Mocha 2	5	2	3	—	0	0	0	—	00.0	Agriculture	ca. 1250 A.D.	(11)
Azapa 142	9	3	6	—	0	0	0	—	00.0	Colonial	ca. 1550 A.D.	(7)
Huantajaya 1	2	—	2	—	0	0	0	—	00.0	Colonial-miners	No date	(7)
Total	264	154	110	—	6	3	3	—	2.3			

[1] (1) Standen and Nuñez, 1984; (2) Núñez, 1969; (3) Soto, 1974; (5) Focacci and Erices, 1973; (4) Santoro, 1980a; (5) Focacci, 1982; (6) Muñoz, 1982; (7) On file Lab. Antropología Física, Universidad de Tarapacá; (8) Santoro, 1980b; (9) Focacci, 1985; (10) Standen and Sanhueza, 1984.

TABLE 4. Incidence of EAE in the highland sites

	Individuals studied				Individuals with exostosis							
Sites	N	F	M	I	n	F	M	I	%	Economy	Dates	Source[1]
Patapatane C1	1	1	0	—	0	0	—	—	00.0	Hunting-gathering	4950 B.C.	(1)
Quitor 2	100	—	—	—	0	—	—	—	00.0	Agro-pastoral		(2)
Quitor 6	250	—	—	—	0	—	—	—	00.0	Agro-pastoral		(2)
Solor 3	53	—	—	—	0	—	—	—	00.0	Agro-pastoral		(2)
Seq. Alam. Aseq.	140	—	—	—	0	—	—	—	00.0	Agro-pastoral		(2)
Usamaya 1	4	2	2	—	0	0	0	—	00.0	Agro-pastoral	ca. 1350 A.D.	(3)
Pukara 3	1	0	1	—	0	0	0	—	00.0	Agro-pastoral	ca. 1350 A.D.	(4)
Total	549	3	3	—	0	0	0	—	00.0			

[1] (1) Standen and Santoro, 1995; (2) Munizaga, 1964; (3) Sanhueza and Olmos, 1981; (4) On file Lab. Antropología Física, Universidad de Tarapacá.

heide et al., 1993; Dauelsberg, 1974; Focacci, 1974, 1981, 1985; Munizaga, 1974, 1976, 1980; Muñoz, 1980, 1982; Quevedo, 1984; Rivera, 1980; Rothhammer et al., 1983; Santoro, 1980a,b; Schiappacasse and Niemeyer, 1984; Soto, 1987; Standen and Nuñez, 1984; Standen and Sanhueza, 1984).

The majority of the individuals were studied by the authors, except those coming from the sites listed in Tables 2 and 4. Most crania belonged to mummies that were previously autopsied. The autopsy records are on file at the Arica Archaeology Museum. Individuals were sexed by external genitalia, and in a few cases, on pelvis and skull morphology. Only adult crania (above 17 years old) were studied. Our previous work has shown that EAE is absent in fetuses, newborns, and children (Standen et al., 1984, 1985). Epiphyseal fusion and dental development were used to exclude younger individuals from the study.

Ear canals were visually inspected with direct light and a 20× magnifying glass to verify the presence or absence of the exostosis. Only crania with clear visibility (e.g., free of soft tissue) of at least one ear canal were used. If the exostosis was present, four main variables were evaluated: (1) size: small (blocking less than 1/3 of the canal), medium (blocking between 1/3 and 2/3) and large (blocking more than 2/3), (2) location: whether the EAE occurred in the roof or floor, or in the anterior or posterior wall of the ear canal, (3) shape: spheroid or ovoid, and (4) side: unilateral or bilateral.

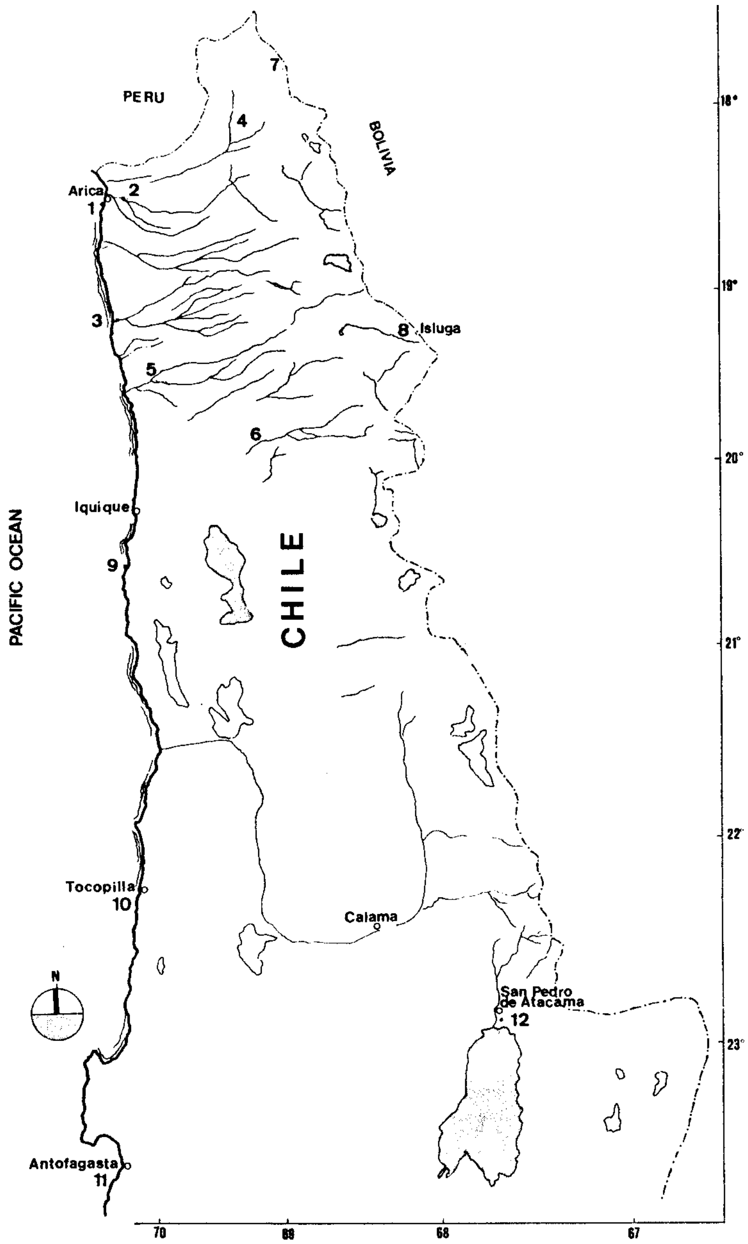

Fig. 1. Map showing the sites studied.

We used the location and shape variables to evaluate whether EAE was part of the tympanic plate or an independent phenomenon.

To explain the incidence of EAE, coastal populations were divided into those of the fertile coast, with river basins draining into the Pacific, and those of the arid coast (Nuñez, 1983). The valley populations correspond to cemeteries located 10–100 km inland with an elevation range of 100–2,000 m, and, the highland individuals came from cemeteries found at 2,500 to 4,000 m of elevation.

TABLE 5. Characteristic of the EAE

EAE	Archaic fishers		Formative		Late fishers	
	%	Sample	%	Sample	%	Sample
Size						
Small	80.8	(21/26)	55.2	(16/29)	54.5	(12/22)
Medium	15.4	(4/26)	31.0	(9/29)	27.3	(6/22)
Large	4.0	(1/26)	13.8	(4/29)	18.2	(4/22)
Location						
Roof	7.7	(2/26)	10.3	(15/29)	9.1	(1/22)
Floor	0.0	(0/26)	0.0	(0/26)	0.0	(0/26)
Ant. wall	26.9	(7/26)	10.3	(15/29)	18.1	(4/22)
Post. wall	42.3	(11/26)	51.5	(15/29)	45.5	(10/22)
Both walls	23.1	(6/26)	27.6	(8/29)	27.3	(6/22)
Shape						
Spheroid	11.5	(3/26)	24.1	(7/29)	13.6	(3/22)
Ovoid	76.9	(20/26)	72.4	(21/29)	86.4	(19/22)
Diffuse	11.5	(3/26)	3.4	(1/29)	0.0	(0/22)
Side						
Unilateral	38.5	(10/26)	55.2	(16/29)	31.6	(7/22)
Bilateral	34.6	(9/26)	41.4	(12/29)	68.2	(15/22)
Undetermined	26.9	(7/26)	3.4	(1/29)	0.0	(0/22)

RESULTS

Archaic fishers (7000 to 2000 B.C.)

Based on subsistence strategies, it was found that hunter-gatherer-fishers associated with the Chinchorro culture, from Acha 2 to Playa Miller 8, had 27.7% (26/94) EAE (Table 1). As expected males were more affected than females, 36.7% (18/49) and 12.8% (5/39), respectively. This difference was statistically significant ($X^2 = 6.4$, df = 1, $P < 0.05$). Of the 26 Chinchorro fishermen with EAE, 69.2% (18/26) were males and 19.2% (5/26) were females. For 11.5% (3/26) the sex was undetermined. The sizes of the exostoses (n = 26) showed that 80.8% had small growth, 15.4% medium-size growth, and only 4% had large exostoses. Most, 42.3%, occurred in the posterior wall, while 26.9% were in the anterior wall, 23.1% in both walls of the auditory canal, and 7.7% occurred in the roof of the canal. Analysis of shape indicated 76.9% were ovoid and only 11.5% were spheroid. Diffuse growth represented 11.5%. Bilateral growths were in 34.6% of the population and 38.5% were unilateral (six in the right canal and four in the left) (Table 5). In the remaining 26.9%, side could not be determined due to the inability to observe the ear canal. In these instances the auditory canal had soft tissue or was broken.

Formative populations (1500 B.C. to 500 A.D.)

Combining the Formative individuals of the fertile and dry coast produced 42.7% (32/75) of EAE. This value included the samples from Quiani 7 to Garibaldi (Table 1) and those of Cañamo 3 (Table 2). Contrary to expectations, males and females had no significant differences in the incidence of EAE with 43.6% (17/39) and 40% (14/35), respectively ($X^2 = 0.098$, df = 1, $P > 0.05$). Of the 22 persons with EAE, 53.1% were males and 43.8% females. Combining both sexes resulted in 55.2% with small, 31% medium, and 13.8% large exostoses, blocking nearly all the canal. The exostoses were located in the posterior wall 51.5% of the times, 10.3% in the anterior wall, 10.3% in the roof, and 27.6% were double, occurring in the anterior and posterior wall. Oval shapes occurred 72.4% and spheres 24.1% of the time, while 3.4% had diffuse growths. Bilateral growths represented 41.4% and 55.2% were unilateral (seven in the right canal and nine in the left) (Table 5) while the remaining 3.4% could not be scored due to presence of soft tissue.

Late fishers with agriculture (1000 to 1450 A.D.)

Late fishing populations of the fertile and dry coast which were also practicing agricul-

ture had 35.6% (36/101) EAE. This value included the samples from Playa Miller 4 to Camarones 9 (Table 1) and those of Auto Club to Punta Blanca (Table 2). As expected males had a significantly higher incidence of EAE than females, 46.9% (15/32) and 20% (5/25), respectively ($X^2 = 4.5$, df = 1, $P < 0.05$). Of the 36 individuals affected, 41.7% (15/36) were male and 13.9% (5/36) females (Tables 1 and 2). The remaining 44.4% (16/36) were not sexed. Sizes of EAE were: small 54.5%, medium 27.3%, and large 18.2%. Within the ear canal, 45.5% occurred in the posterior wall, 13.7% in the anterior wall, 10% in the roof and 27.3% were double, occurring in the anterior and posterior wall. Oval shapes represented 86.4 and 13.6% were spheroid. Bilateral growths were found 68.2% of the time and 31.6% were unilateral (four in the right canal and three in the left) (Table 5).

Analysis by elevation

The highest incidence of EAE was found among all coastal populations with 30.7% (103/336) (Tables 1–4) with significant differences between males and females: $X^2 = 10.6$, df = 1, $P < 0.05$. If the coastal sample is divided by habitat, fertile vs. arid coastlines result in nonsignificant differences of 30.6% (87/284) and 30.8% (16/52) ($X^2 = 0.23$, df = 1, $P > 0.05$). The valley societies, such as Azapa, Tiliviche, and Tarapacá, in contrast, had 2.3% (6/264) EAE (Table 3). Two inland valley cemeteries, however, were exceptional: Azapa 70 had 21.4% (3/14) EAE and Azapa 14 had 20% (2/10). Further inland, in the highland the incidence of EAE was reduce to zero (0/549) (Table 4).

DISCUSSION

The results indicate that EAE was a condition associated mainly with coastal populations. This points towards a causal explanation of environmental factors and an activity induced condition, rather than a genetic etiology. As was found from the clinical data, we postulate that the presence of EAE in coastal Chilean populations was a consequence of habitual maritime activities, such as diving and shellfishing, which triggered these chronic osseous formations.

Location and shape of the EAE seem to shed light on the etiology also. Regardless of time EAE was basically located on the posterior wall, showing that these growths were completely independent of the tympanic plate development. Moreover, the shape of EAE was clearly defined, most ovoid and spheroid, indicating that they were not an inflammation of the tympanic plate. Some growths were large enough to completely occlude the auditory canal.

As was noted by Kennedy (1986), EAE is common in coastal populations that inhabited 30–45° latitude north and south. In these latitudes the water is cold, with a temperature normally below 19°C. The cold water predisposed them to develop EAE. Our research indicates that EAE was also present in lower latitudes (17° to 26° south).

Although today the majority of the mollusks correspond to an intertidal habitat (Osorio, 1979), few scholars have quantified the *taxa* of archaeological marine remains for northern Chile (Llagosteras, 1979, 1993). The coastal middens and the presence of EAE show that the Arica people practiced extensive shellfish and fish gathering. Moreover, archaeological studies have revealed that the Atacama coast was populated starting 9,000 years ago by hunter-gatherers-fishers who had a highly specialized maritime subsistence (Bird, 1943; Llagosteras, 1979; Muñoz et al., 1993; Nuñez, 1983, 1986; Schiappacasse and Niemeyer, 1984). Artifacts such as shellfish hooks or cactus hooks, sinkers, harpoons, and a prying tool found in the coastal shell middens and cemeteries testify to a highly specialized maritime subsistence. These early fishers, today known as Chinchorro, developed complex mortuary rituals involving artificial mummification of their dead (Allison et al., 1984; Arriaza, 1995; Bittmann and Munizaga, 1979; Nuñez, 1969; Schiappacasse and Niemeyer, 1984; Standen, 1991; Uhle, 1919).

From an evolutionary perspective, it is interesting to point out that the early hunter-gatherers-fishers (about 7000–2000 B.C.) had a lower incidence (30.7%) of EAE, than later fisherfolk (35.6%) from the same area that were complementing their subsistence with agricultural products. Since the late coastal fishermen were depending less on maritime products, we expected to find a lower inci-

Fig. 2. Large auditory exostosis in a male fisher (Camarones 9 T8).

dence of EAE: the result proved otherwise. The Formative Period groups with incipient agriculture and late fishermen with agriculture, presented a greater incidence of EAE (47.7 and 35.6%, respectively) than the early fishermen. This indicates that the later populations were becoming even more dependant on coastal resources and that the ocean continued to be essential to their economy. Thus, the advent of agriculture did not mean abandonment of a maritime way of life, but only a shift or a supplemental source in their diet. We hypothesize that those who devoted themselves to fishing were probably intensifying their activities to create a surplus for trading with inland agro-pastoral groups.

Greater dependency on ocean resources is also reflected in the size of the EAE, since there was a direct correlation between size and chronological sequence (Fig. 2). The Archaic groups had only 4% of large EAE, while Formative and late groups had 13.8 and 18.2% of large EAE, respectively. If it is assumed that the size is directly related to the time expenditure in the water, then the late fishermen spent more time diving. Another explanation is that post-Archaic groups dove in deeper waters, increasing the likelihood of ear irritations. This greater ocean dependency is also reflected in the degree of bilaterality, which increased with later populations. The Archaic groups had 34.6% bilateral occurrence, the Formative 41.4%, and the late fishermen 68.2%. Most growths were ovoid and located in the posterior wall of the ear canal. Considering that there is an increase in the incidence of both variables (size and bilaterality) through time, it appears that, indeed, the later fishers with agriculture actually had a greater dependency on maritime resources.

If we accept the hypothesis that EAE is the consequence of an activity-induced pathology then it is interesting to discuss the division of labor. Among the early fisherfolks, males had a significant higher incidence of EAE than females, 36.7 and 12.8%, respectively. These values validate the hypothesis that there was sexual division of labor, with males doing most of the ocean collection. However, in the Formative populations, which had incipient agriculture, males and females did not show significant differences of EAE. This could indicate that females were more actively engaging in procurement of coastal resources. It is not understood which were the cultural or economic factors that triggered this change. During

the Agro-pastoral Period, despite a rise in the incidence of EAE, harvesting from the ocean became a male duty once again, with 46.9% for males and 20% for females.

The relationship between EAE and food procurement in cold waters seems obvious. Despite the increase of female participation during the Formative period, the overall greater incidence of EAE in males indicates that most of the underwater procurement of marine resources was basically a male activity. Even today, in Arica, the few local divers are all males. It is interesting, however, to point out that in the south of Chile, among the Alacaluf and Yaghan Indians, the women dove for fish and mollusks. Males, in contrast, rarely swam and used harpoons to fish (Emperaire, 1963, p. 182; Bridges, 1988, p. 63).

Of all the coastal cemeteries studied only two did not present any evidence of (0%) EAE. These were Camarones 8 in the fertile coast and Auto Club in the arid coast of Antofagasta. It is not clear why this is the case. One explanation is that the sample size was too small (n = 8 and n = 6, respectively). Another is that these coastal people represented inland agriculturalist colonies or *mitimaes* living at the coast. They may have acted as middle men to control and direct the use of resources. This explanation, however, needs further investigation.

It is clear that there is an inverse correlation between distance to the coast (and elevation) and the incidence of EAE. Ancient Andean populations living closer to the coast had a greater incidence of EAE. This value diminished for valley populations (2.3%), and was zero for the highlanders. The Arica inland or valley populations with EAE corresponded to the Alto Ramirez cultural phase (Focacci and Erices, 1973; Muñoz, 1980; Rivera, 1980, 1984). According to the archaeological record, the Alto Ramirez people had a circum-Titicaca origin, displaying highlander agro-pastoral subsistence patterns in the lower valleys. Yet, the presence of EAE in the Alto Ramirez people indicates that a coastal component was integral to this cultural phase. Either local coastal people were buried inland or Alto Ramirez immigrants themselves harvested from the ocean. Perhaps the highlanders intermarried with coastal groups. Later, during the Christian period, small chiefdoms emerged in this region controlling lowland and highland valleys based on agriculture and herding. From the ethnographic literature, it appears that at this time inland people traded heavily with the coastal inhabitants. Perhaps EAE can be used to evaluate to what extent adults from coastal areas moved to higher elevations.

When the fertile and arid coasts were compared we expected to find a greater incidence of EAE in the latter. This assumption was based on the fact that the people in the arid zone would have had less access to agricultural products. As a consequence, a greater ocean dependence would have been necessary. However, this was not the case, since the percentages of EAE are equal. Both groups had about 31%. These values indicate that the people of the arid coast were trading with inland groups and indeed complementing their diet with non-local products (maize, coca, etc.) as has been suggested by various Andean scholars.

CONCLUSIONS

There is a significant association between EAE, environment, and sex. EAE is a coastal condition. Our findings are in agreement with the cold water hypothesis synthesized by Kennedy (1986). Also, the majority of the EAE were located in the posterior wall, showing that their genesis was independent of the tympanic plate development. EAE is basically a condition of coastal males. This difference is related to a division of labor where men were doing most of the underwater food procurement.

The size and bilaterality of the EAE increased with time. Thus, contrary to expectations, with the advent of agriculture, the coastal Arican populations increased their ocean harvests, rather than decreasing them. In a bioarchaeological setting, EAE can be a useful tool for evaluating subsistence bases and division of labor and economy, especially if combined with other archaeological data. Furthermore, the high incidence of EAE in genetically unrelated prehistoric populations, such as the Indian Knoll and Santa Catalina people of North America (Kennedy, 1986) and our Andean sample, points to an

aquatic activity-induced condition rather than gene flow of an autosomal trait.

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